Anisotropic radar reflections in ice-sheets - Potential mechanisms and implications

Contact: reinhard.drews@awi.de

R. Drews[1,2], O. Eisen[2], N. Neckel[1,2], W. Rack[1], D. Steinhage[2]

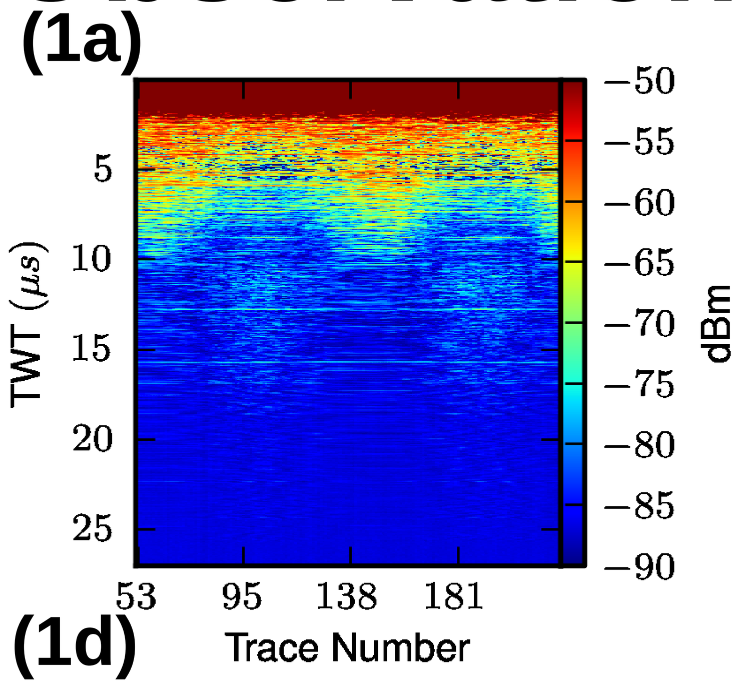
[1]: Gateway Antarctica, University of Canterbury, Christchurch, New Zealand /[2]: Alfred Wegener Institute for Polar- and Marine Research, Bremerhaven, Germany

Introduction

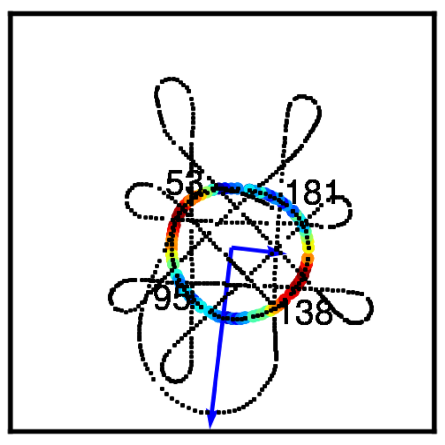
Polarimetric ice-penetrating radar measurements aim to retain anisotropic features from within the ice. Recent studies ([1], [2]) in Antarctica showed that especially in deeper ice, the formation of flow induced aligned crystal orientation fabric (COF) can be a main mechanism for a polarization-dependent response in the radar data. As aligned crystal significantly alters the flow behavior of ice, this is an important implication for ice-sheet modeling. In this study we also investigate the effect of anisotropic inclusions (e.g. air bubbles) which may act as strain markers within the ice.

Observation

(1a)

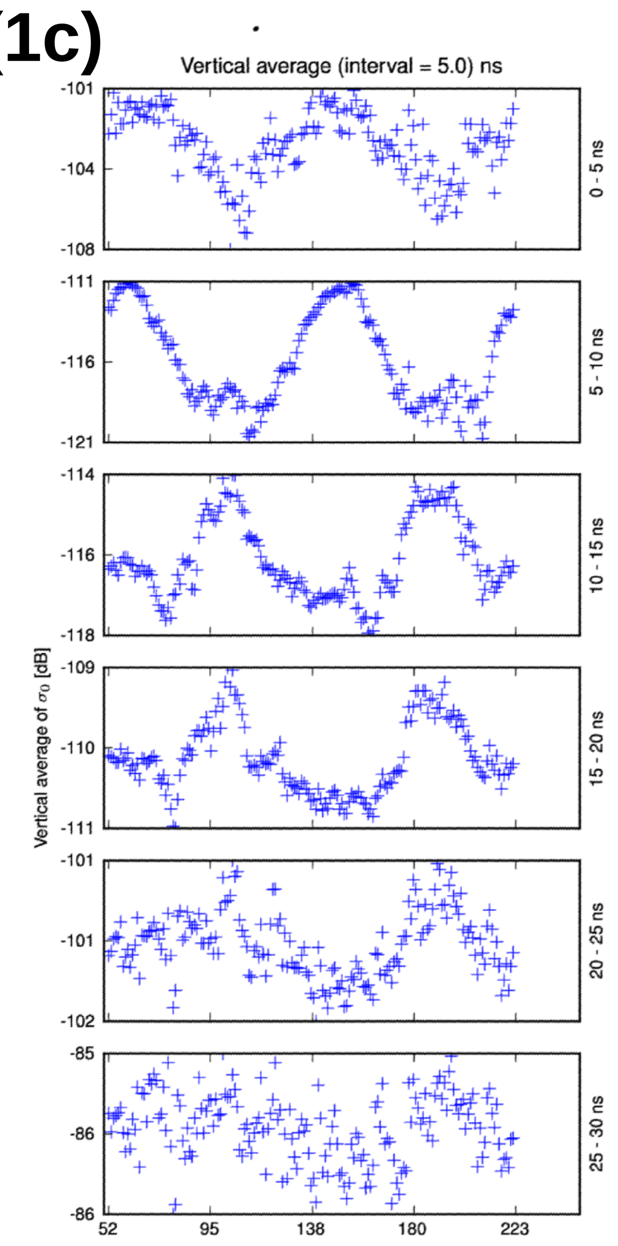


(1b)

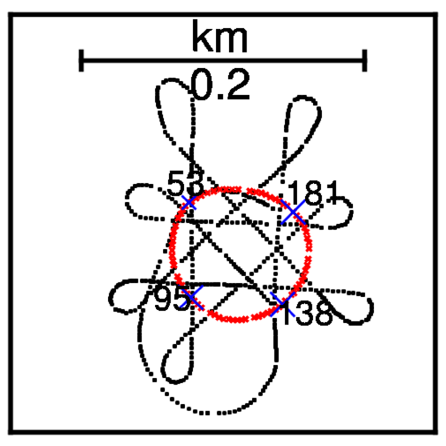


5-10 ns (color-coded)

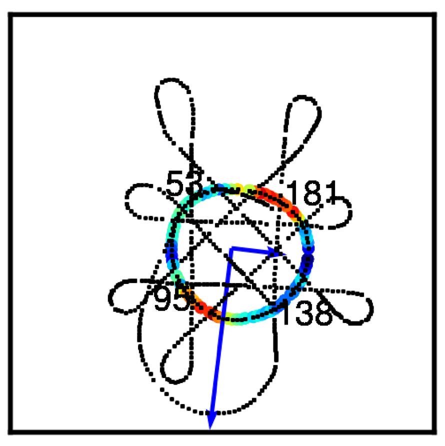
(1c)



(1d)



(1e)



10-15 ns (color-coded)

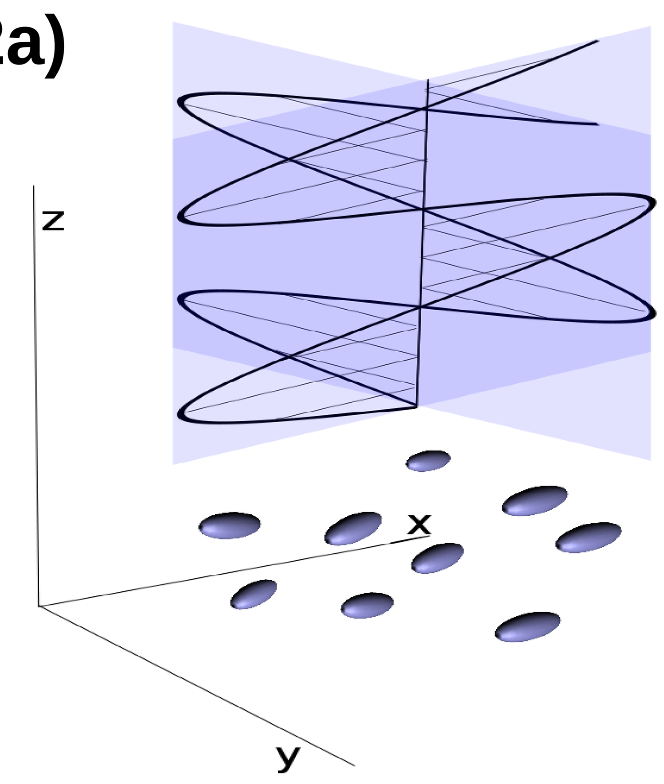
Circular radar profile (airplane on the ground)

(1a): Backscattered power of circular radar profile shown in **(1c)**; **(1b),(1e):** The sinusoidal pattern exhibits a 180°-symmetry. In the upper 400 – 900 m (~5–10µs TWT) it is maximal in the direction of minimal surface strain. From 900 m down to ~1300 m (~15µs TWT) the pattern shifts by 90°; (c) the depth averaged attenuation corrected profile shows changes in reflection power of ~3–5 dB. A 45° symmetry pointing to birefringence is not dominating.

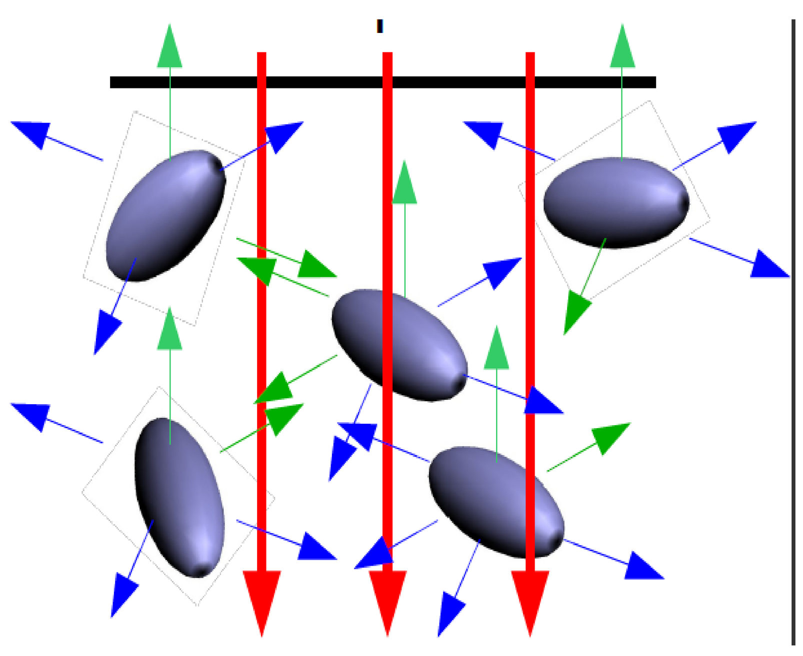
Method

We use volume scattering models to estimate both, the effect of deformed air bubbles and varying COF. For the airbubbles we use an adapted model based on the radiative transfer equations [3]. This includes the full angular dependency, varying orientation distributions and first order multiple scattering. For the COF we plan to implement a random medium model for a (non-tilted) biaxial medium (work in progress).

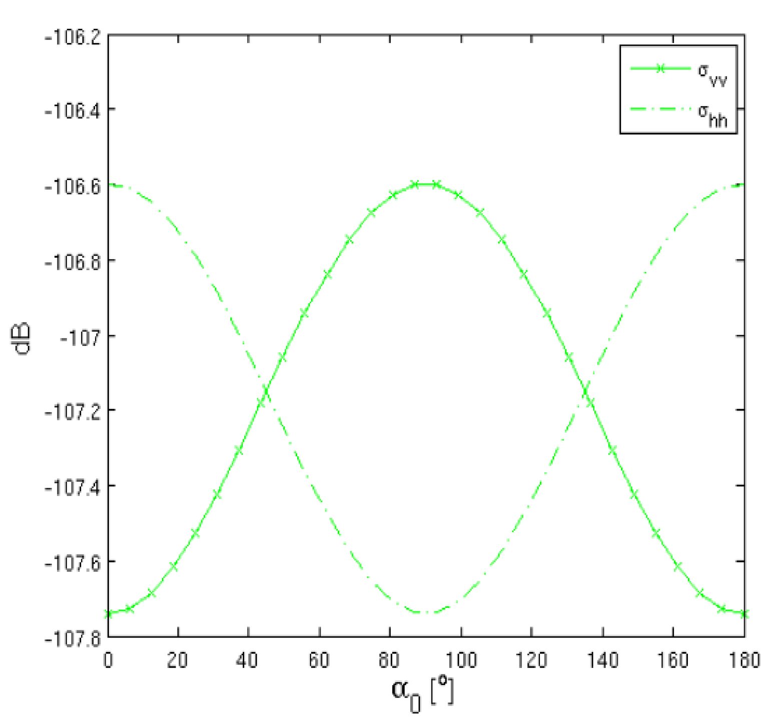
(2a)



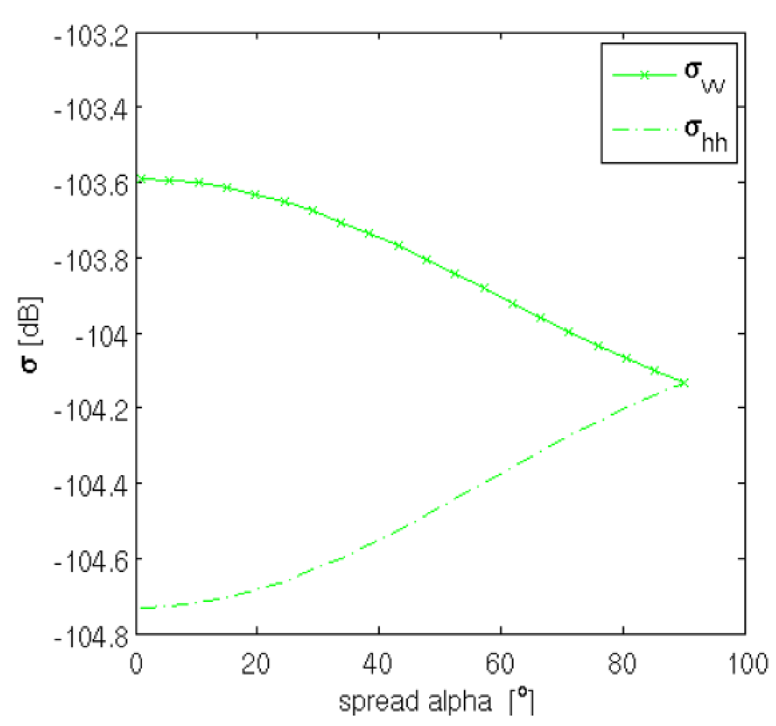
(2b)



(2c)

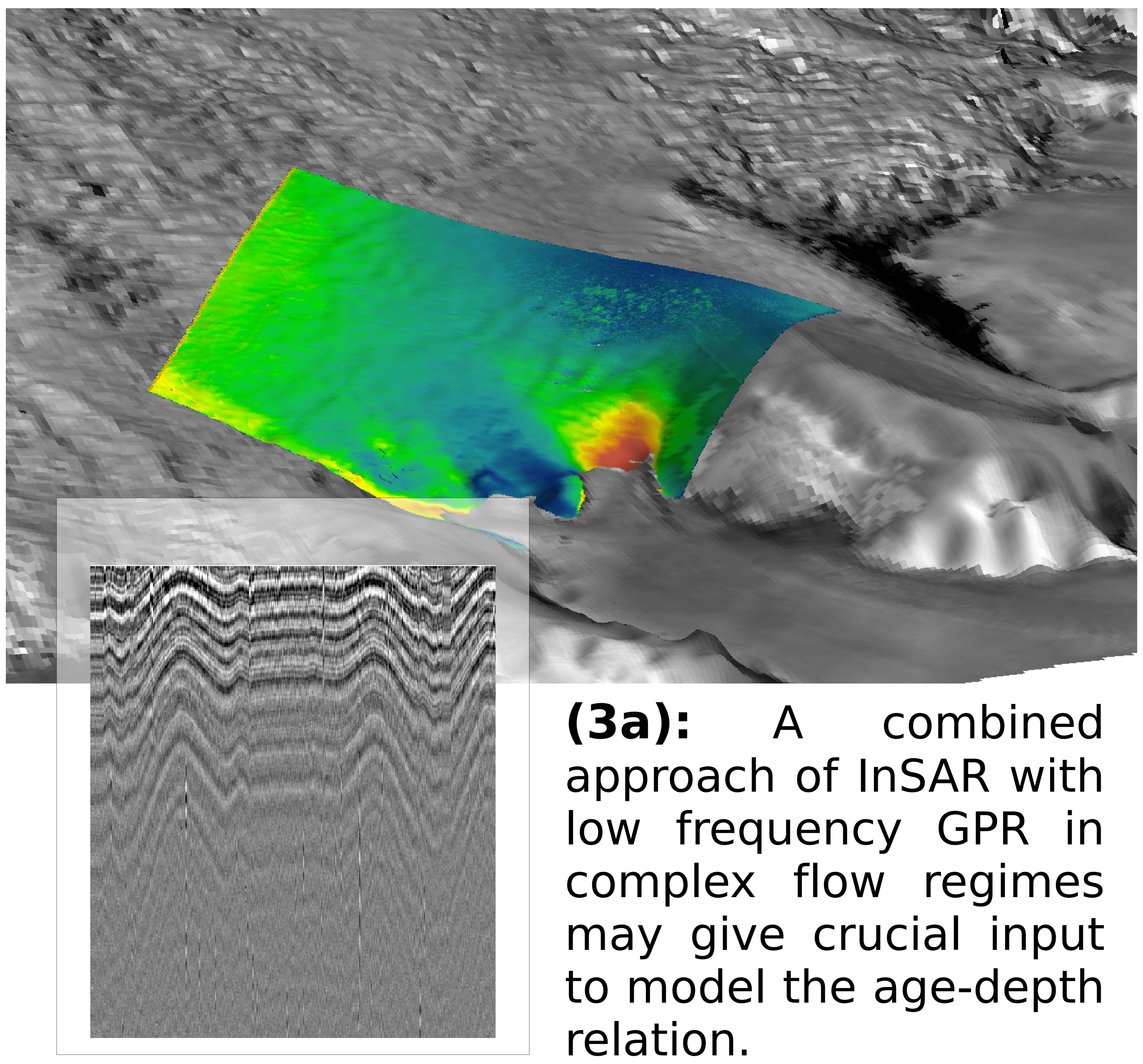


(2d)



Model visualisation and outcome

(2a)-(2b): Changing polarization is treated as as a limiting case of vertical and horizontal polarization for nadir inidence. First order multiple scattering is allowed (but does not play a primary role); **(2c):** Confirms the 180° symmetry for the backscatter coefficients if the bubbles are rotated in the horizontal; **(2d)** Estimates the effect of order in the orientation distribution from fully aligned to fully random.



(3a): A combined approach of InSAR with low frequency GPR in complex flow regimes may give crucial input to model the age-depth relation.

Results and Outlook

The model outcomes with respect to deformed airbubbles reproduce the observed symmetry, but seem small in magnitude. To classify the effect, a comparison with the volume scattering for COF is neccessary.

Once geophysical process is identified **internal stress and strain rates may be identified on a larger scale via interferometric SAR and low frequency radar studies (3a).** This serves as input for ice-sheet modelling for precise ice-core dating in complex flow regimes (triple points).

References

[1]: Eisen et al., *Direct evidence for continuous radar reflector originating from changes in crystal-orientation fabric*, The Cryosphere, 1, 1–10, 2007

[2]: Fujita et al., *Radio-wave depolarization and scattering within ice sheets: a matrix-based model to link radar and ice-core measurements and its application*, J. Glaciol., 52, 407–424, 2006.

[3]: Tsang et al., Radiative transfer theory for active remote sensing of a layer of small ellipsoidal scatterers, Radio Science, Volume 46, No. 3, 1981